A new fabricating technique of refiner plate

XIANG Hong-liang

College of Mechanical Engineering of Fuzhou University, Fuzhou 350002, P. R. China

Abstract: It was discussed how refiner plate is produced by a new process, such as three dimension making die with computer technology, shell molding, optimizing the alloy and controlling shakeout time with computer. Results confirmed that lead-time was decreased and product customization was improved in making die by using computer technology. At the same time, precision molding can decrease the reject ratio of refiner plates, and optimizing the alloy and shakeout time can eliminate the need for heat treatment. The new fabricating process showed several advantages over the traditional process in increasing toughness, better casting precision, elimination of the annealing treatment stage and raising production efficiency.

Keywords: Refiner plate; Die making;precision molding; Metal smelting

CLC number: TS733.3 **Document Code:** A **Article ID:** 1007-662X(2005)04-0296-03

Introduction

For making fiberboard or pulping from wood raw material, wood chips are processed by refiner plate that is very easily broken (Mihelich Scholl *et al.* 1997). At the time, the working life of refiner plates must be sufficient for the fiberboard industry, and then refiner plates should be abrasion-resistant, wearing-resistant, and high in toughness. They usually have a complex structure and abrupt change in thickness, which makes them difficult in making mould and casting process. As a casting part, it should be free of defects such as sand eyes, shrinkage and shrinkage porosity, crack and so on. There are also some special requirements such as high precision in dimensions and surface roughness. However, the long time and high costs of individual product customization limit providing service to their customers. Several reasons associated with providing hindrance included the lack of supporting technology, design standards, product modularity and trained support personnel. All these make the fabrication process very difficult. This study is to find a proper technique, which can easily control the whole fabricating process.

Structure of refiner plate

A set of refiner plates consists of a circle that is mounted on a disk. Its tooth mode depends on the kinds of pulp wanted to produce. Of hundreds of models. Tooth model is composed of tooth width, tooth thickness, distance between teeth, and tooth array modes. The arranging modes (Fig. 1) can be divided into radial, tangent direction and parabola mode, etc. The plate has three regions, a breaker bar section where wood chips are broken into smaller fragments, intermediate refiner zone where the wood chip fragments are broken into small fiber bundles, and the refining zone where the fiber bundles are put under shear by rolling and twisting and are exposed to tension and normal stresses by bending, crushing, pulping and pushing actions (Scholl *et al.*1997).

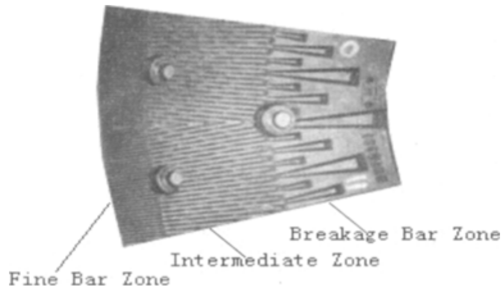

Fig. 1 Zone of the refiner plate

Process of making refiner plate

The traditional making process of high chromium white iron or alloy steel plates is: product design→two-dimension drawing →die process → molding → mating material → melting→ precision casting → annealing treatment→ surface spraying sand → machining →adjusting static and dynamic balance.

The fabricating technique for refiner plate has been also greatly improved along with the development of industry and computer technologies. A new fabricating process has been established, which is more intelligent and can be divided into four phases: computer-aided drawing → numeric control die-machining → precision molding → adjusting static and dynamic balance.

Making die for refiner plate

According to demand-supply relationship in paper industry and the law of market value different refiner plates need to meet the demands. Therefore, rapidly making die technique for refiner plate is the demand not only of market but also of the factories for their own interests. In the refiner plate design and casting, the traditional process of customizing a refiner plate pattern for sand casting is shown in Fig. 2a. First, salespeople meet with customers to identify their particular pulp requirements, and then designers develop a new 2-D model. Finally, craftsmen or production engineers develop prototypes for customer verification. In the traditional product development and customization process, a long time is spent on translating customer CAD drawing and

Biography: XIANG Hong-liang (1972-), male, Ph. Doctor in College of Mechanical Engineering of Fuzhou University, Fuzhou 350002, P. R. China. (E-mail: hlxianggg@sohu.com)
Received date: 2005-03-18
Accepted date: 2005-10-21
Responsible editor: Zhu Hong

prototype development for customer design verification. Several prototypes are usually required before customers are completely satisfied. The lack of associability between the two-dimensional model and the manufacturing process can also cause further delays. Every time there is a design change, the numerical control code for prototyping must be manually developed or edited. A new development and customization process to reduce design lead-time and the number of physical prototypes must be made prior to full-scale production. As shown in Fig. 2b, the customer requirements are turned directly into a solid three-dimensional model by changing design parameters in a parametric, feature-based design. By doing so, the amount of time required to develop the product model is significantly reduced. Design verification and computer analyses can also be performed readily once the solid model has been created. By employing advanced solid modeling software, a significant portion of customer requirement verification can be done electronically on the computer before any real prototypes are produced, which results in the reduction of the number of prototypes. After the customer is satisfied with the three-dimensional solid model on the computer, a solid prototype can be developed to verify requirements. In this new development and customization process, parametric CAD and CAM expedites model development, prototype development, and design verification by associating them with only one model: the product model. Moreover, in the parametric associative software tools, a change in the product model will automatically propagate changes in other engineering models such as the casting die patterns and numeric control programs for making the tooling, machining the casting die and casting. Fig. 3 shows the refiner plates in three-dimension, its mould die and true casting.

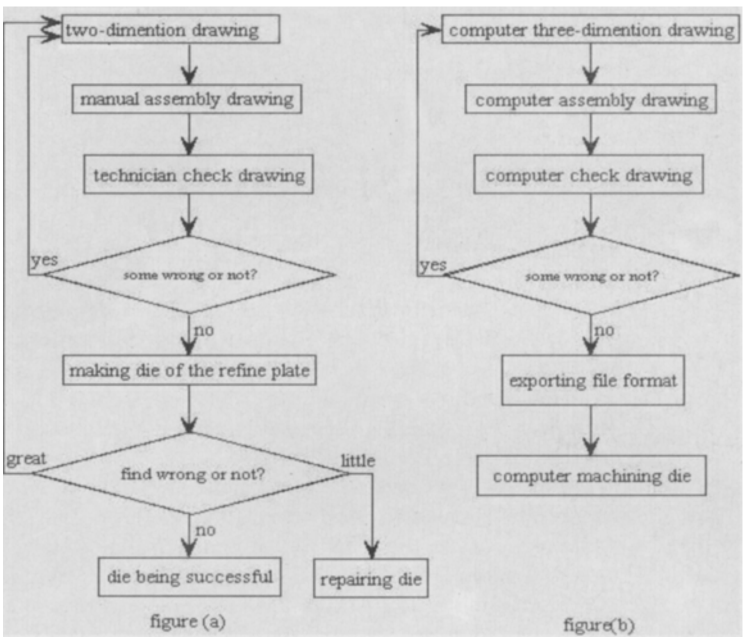

Fig. 2 Comparison of traditional and new process

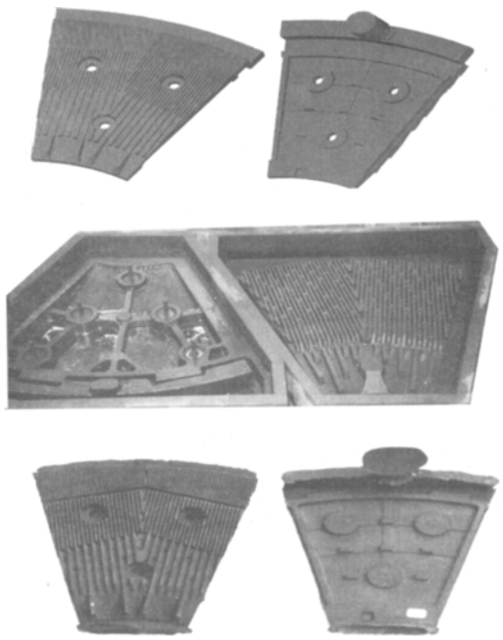

Fig. 3 The new forming process of refiner plate

Precision molding

It is very difficult to strip by normal molding method and to repair the destroyed parts of sand mould because the teeth of refiner plate are very small (4 mm in height, 2 mm in thickness and 2.5 mm distance between teeth) and there are many requirements such as CT5 for precision dimension and high degree of surface finishing (Fig. 4). Although it is the most optimal choice to use shell molding, there is a flaw which is a large amount of gas release resulting in gas hole and cold shut defects. During the preparing of shell-sand, the most ideal method is to use smaller quantity of shell-sand resin to decrease the gas release, so that the shell strength is maintained. A further decrease in the quantity of resin can be achieved by adding a new additive called tenacious agent. Table 1 shows the comparison of the shell sand used in Jilin Paper & Pulp Factory (Mark A) and the new shell sand (Mark A). Table (2) shows their some performances. Deflection test conditions are as follows: dimensions of test samples are 22x22x165 (mm); set temperature is 250°C; set time is 10 min. Tensile test conditions are as follows: tensile sample is 8-shape; set temperature is 263 °C; set time is 10 min. The method of LOI (loss on ignition) is: firstly prepare 4 crucible beakers which are clean and dry, then put 2-g shell-sand resins in every beaker, thirdly burn them for 15 min, at last weigh and calculate the percentage of the lost weight in the whole. Gas volume, including the gases derived from resin, water and other substance, should be measured under the condition of 1000 °C by GET-I model gas volume measurer.

Table 1. Shell-sand compositions (%) (Chen 1992)

Mark	Saw sand	Resin	Hardening agent	Tenacious agent	Water	Calcium stearate
A	100	6-7	1	---	1	0.1-0.3
B	100	2.5-3	0.36	0.21	1	0.1-0.3

Notes: A----shell sand of Jilin paper and pulp; B----new shell sand.

Refiner plate abrasive wear affects pulp strength, pulp quality, refining stability, machine runnability and power consumption (Mihelich *et al.* 1972; Thompson *et al.* 1987; Thompson 1990).

Mihelich *et al.* in the 1960s listed burst index, tear index, freeness, specific volume, shives and scattering coefficient as being pulp quality factors that are adversely affected by the wear of refiner plates. The traditional refiner plates were usually made of Ni-hard cast iron. chromium white cast iron or stainless steel, and their toughness and hardness are not sufficient for refiner plates. Thus, optimizing alloy composition and modifying casting process are very important. Table 3 shows the optimizing alloy composition for the refiner plates, and Table 4 proves that the new refiner plates have a higher strength and toughness. The working life of the new refiner plates is up to 1 120 h.

Table 2. Performance comparison

Mark	Deflection performance (Mpa)	Tensile performance (Mpa)	LOI (%)	Gas volume (mL/g)
A	2.7	1.12	7.3	65.6
B	2.6	1.07	3.2	34.4

Notes: A----shell sand of Jilin paper and pulp; B----new shell sand.

Table 3. Compositions of testing materials (%)

C	Si	Mn	Cr	Ni	Mo	V
2.5–2.8	0.7–1.2	0.4–0.80	22–28	0.6–1.1	0.6–2.0	≤0.4

Table 4. Mechanical properties and microstructure

Impact toughness (J/cm^2)	Hardness (HRC)	Microstructure
5.88	52	austenite+ M_7C_3

Notes: impact test sample sizes are 10×10×55(mm).

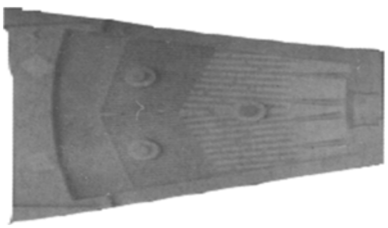

Fig. 4 The sand molding material and casting process

Except modifying the high chromium white irons to strengthen the refiner plate toughness, it is necessary to ensure the shakeout time to be free from heat treatment. By using a computer-controlled temperature to measure equipment, which has 48 channels and is able to adjust the sampling step (the shortest time is 1.2 ms) and continually measure temperature for 6 h, we measured the temperature change during forming the refiner plates. From the cooling curve, liquid/solid phase transition area can be clearly found, which ensures the rationality of shakeout temperature and provides the proof for omit of heat treatment. Its pouring temperature is 1 540 °C, and the temperature will decrease to 1 420 °C immediately after pouring. The temperature of beginning of liquid /solid transition is 1 267 °C. Eutectic point is 1 234 °C. Solid transition temperature is 895 °C. Shakeout can be applied when the temperature drops to 940–960 °C (Fig. 5). This reduces the processes of producing plates and cost, makes the rejection ratio to be zero, and shortens the time of producing refiner plates.

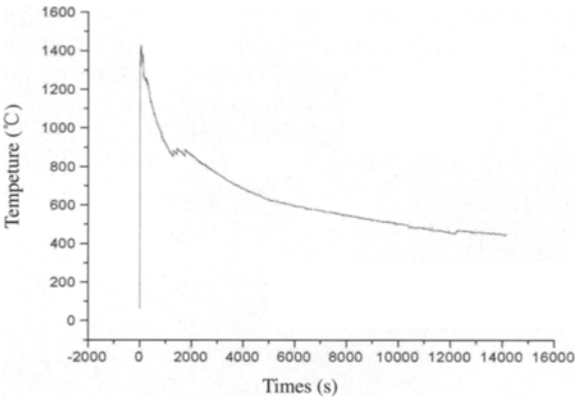

Fig. 5 Casting cooling curve

Conclusions

The new process of making die can facilitate design verification, reduce the lead-time and improve the product customization.

Adding tenacious agent into the shell-sand can decrease the resin quantity, ensure the strength of molding-die and decrease rejection ratio of refiner plates.

Optimizing alloy composition of material for refiner plates increases abrasive resistance and working life of refiner plates.

Shaking out the shell-sand at the optimum time leading to omit the annealing treatment results in decreasing the processes of producing refiner plates and reducing the cost of products.

References

Chen Laigui. 1992. The research of TMP refiner plate [J]. Pulp and Paper Making, (4): 35–36.

Thompson, C.B. 1990. The cavitation erosion resistance of refiner plate alloys [J]. Journal of Pulp and Paper Science, **16**(1): 20–28.

Mihelich, W.G., Wild, D.J, Beaulieu, S.B., Beath, L.R. 1972. Pulp Paper Mag [M]. Canada: Canadian Pulp and Paper Association Press, p78–82.

Thompson, C.B., Garner,A. 1987. Wear Characteristics of Refiner Plates [J]. Pulp and Paper of Canada, **88**(8): 294–297.

Scholl, M., Clayton, P., Jia, Y. 1997. Deterioration behavior of thermomechanical refiner plates [J]. Wear, **203** (3): 65–76.

Thompson, C.B, Garner, A. 1988. The resistance of refiner plate alloys to bar rounding [J].Tappi Journal, **82** (6): 95–100.